Mixing in the TTL diagnosed from the tape recorder of water vapor

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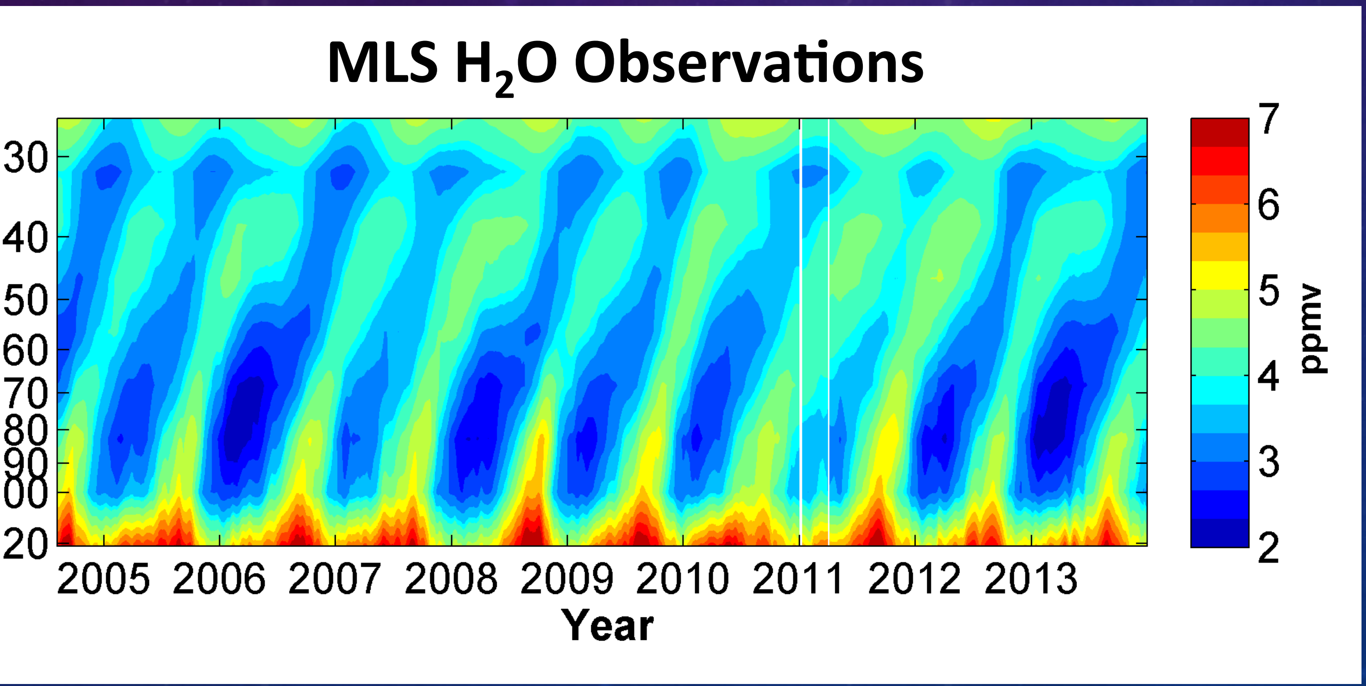
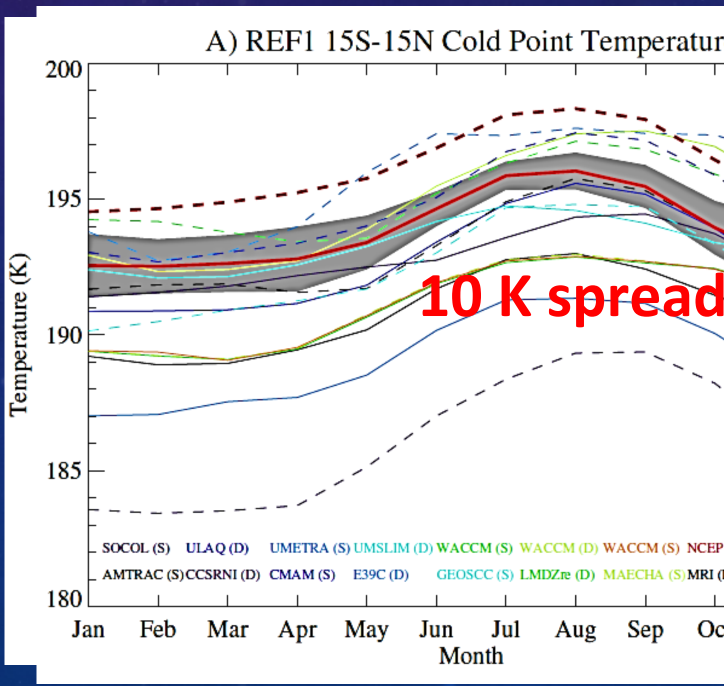
CT3LS Meeting | July 20, 2015

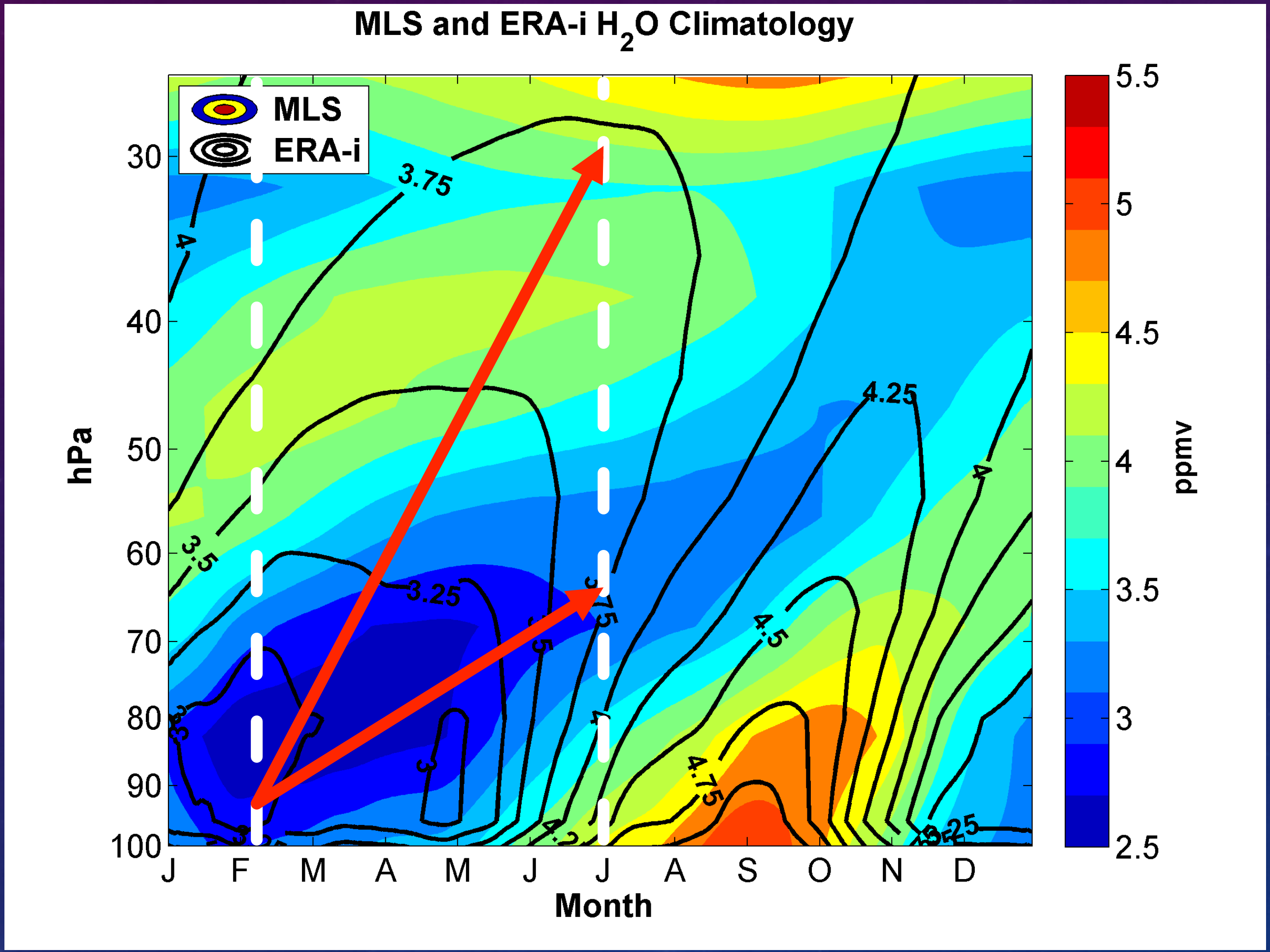
(Gettelman et al., 2009)





Ba

ERA-i is about 3x faster



during 2004-2013

Objectives

How important is mixing?

Can you model the tape recorder in more than one way?

What causes increased transport in other models?

Broad Picture

Modeling TTL dynamics

+

How much water vapor enters the stratosphere?

+

Stratospheric chemistry and surface climate

Data

MLS Observations

ERA-i reanalysis

GEOS CCM

1. Find the effective (total) vertical velocity

2. Model the 3 transports individually to re-create the tape recorder

hase-lagged correlation method

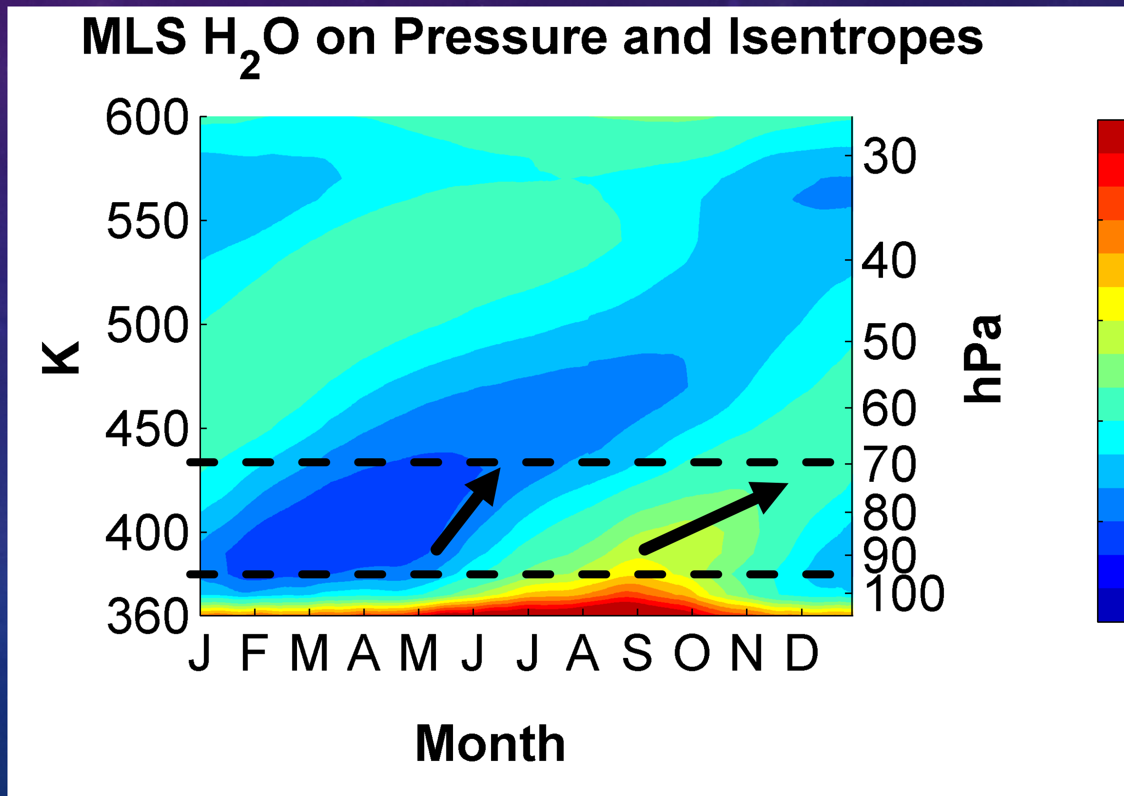
find effective velocity (based on Schoeberl et al., 2008 and Niwano, 2003)

Correlate H_2O at two levels, shifting the data in the top level day-by-day up to 14 months

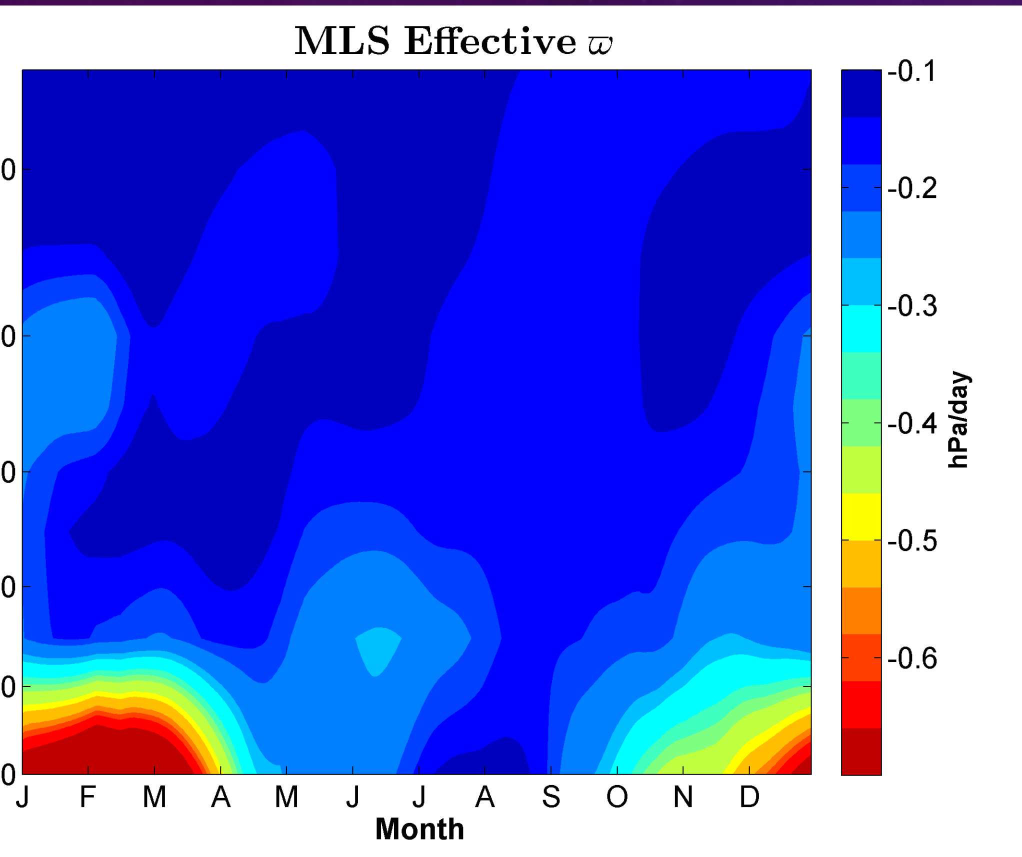
The effective velocity is simply the space between the levels divided by the time lag with best correlation

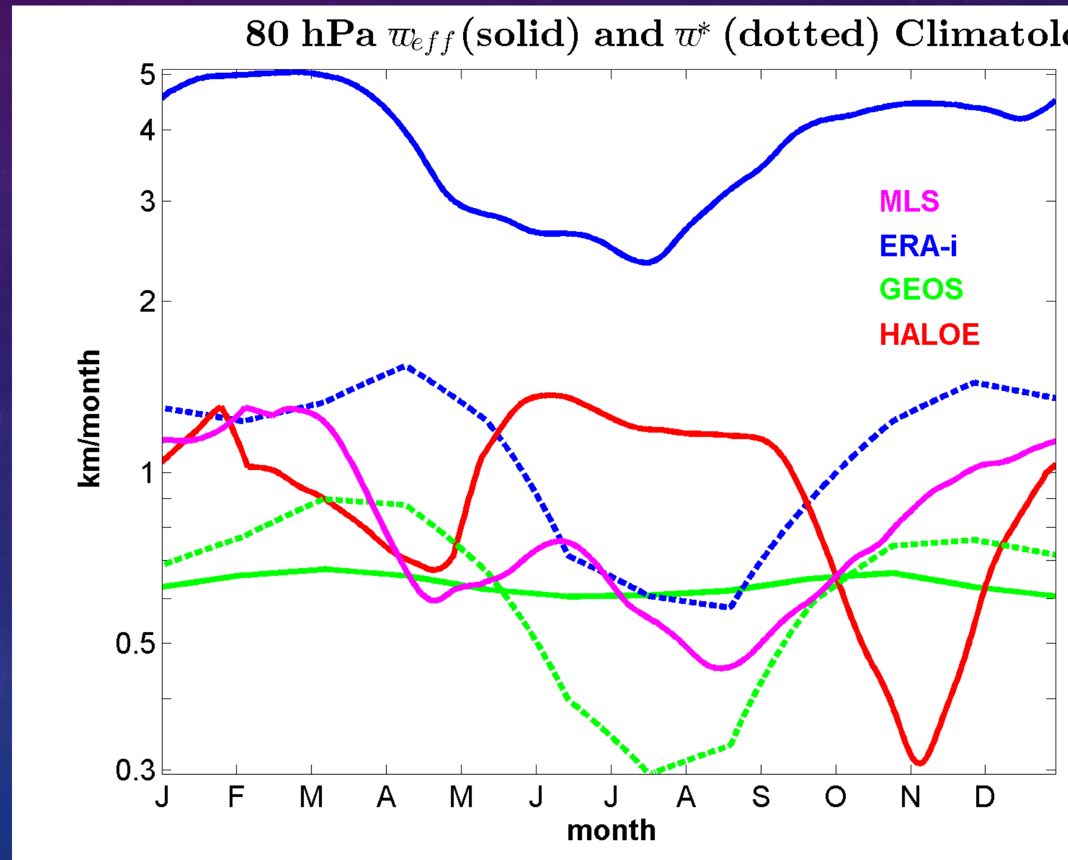
Effective velocity – the transport on all space and time scales

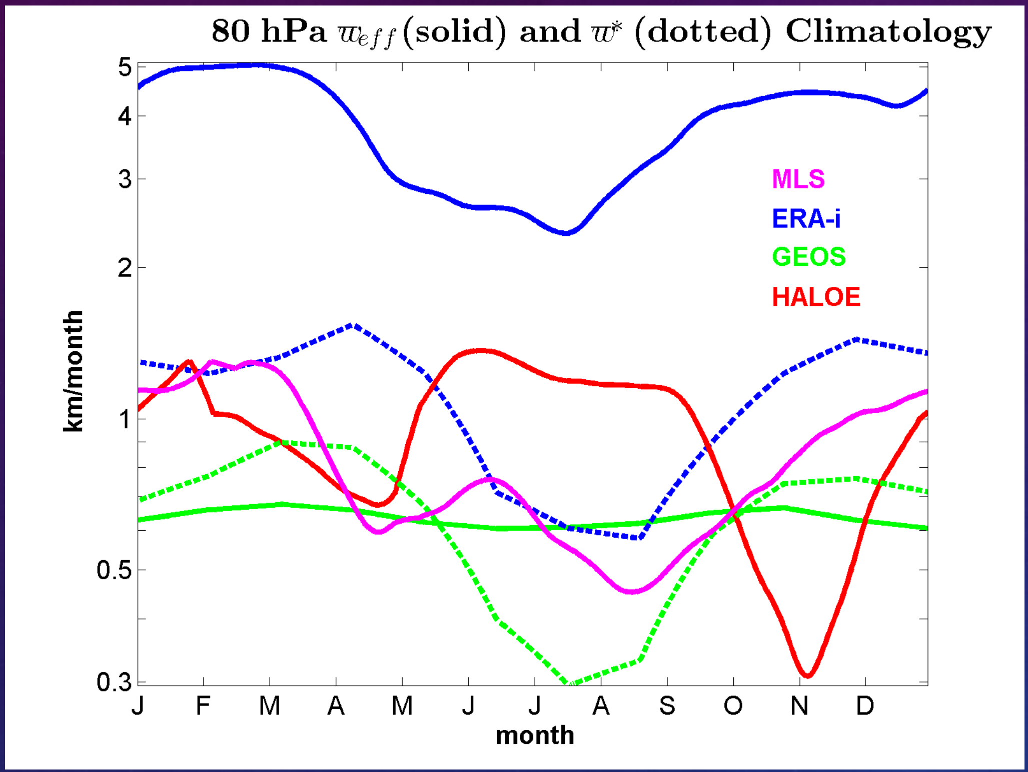
Instead of using 365 days, we use 180 to capture the seasonal cycle (this doesn't hurt the correlation coefficient)



ffective vertical velocity ω







What would MLS's $w↑*$ (dotted line) look like?

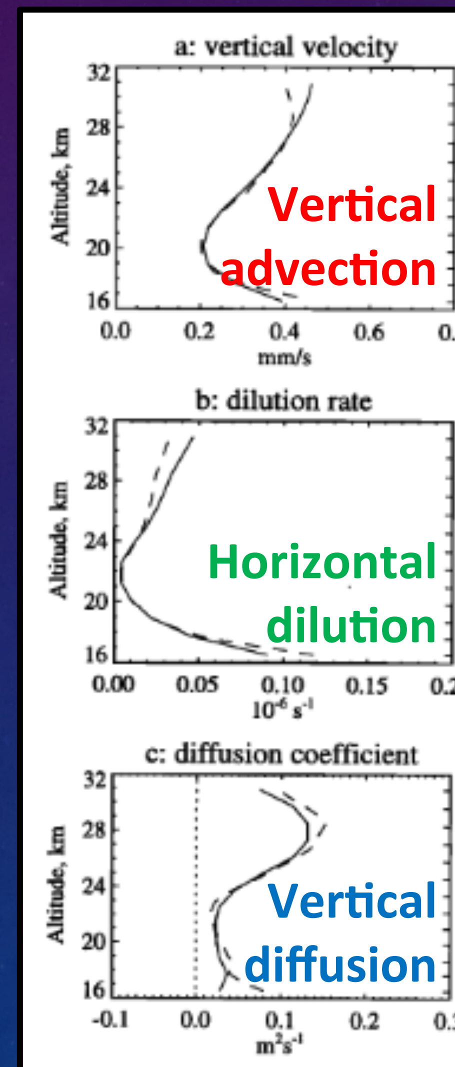
Building upon past work

Mote et al. (1998) defined the tape recorder by a wave solution and used a 1-dimensional model → inverse solved for **annual mean transports**

ically, we represent Ĥ anoma
$\chi = \mathrm{Re} f(z) \exp[i(\phi(z) - \omega t)]$
al and are determined from Ĥ

We use **time-dependent** transports based on the seasonality seen in the effective velocities and literature (Rosenlof (1995); Plumb (2002); Konopka et al. (2009))

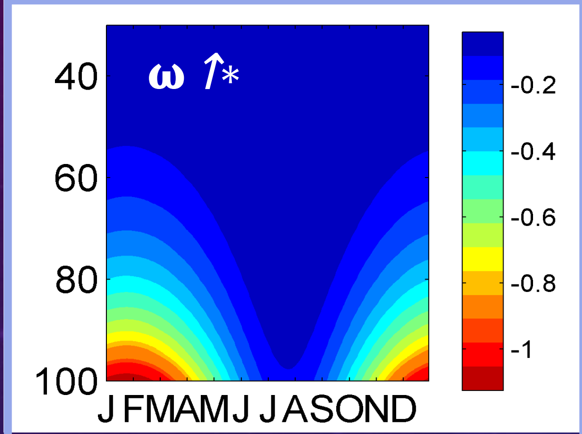
Parameter sweep



Seasonal cycles of transports

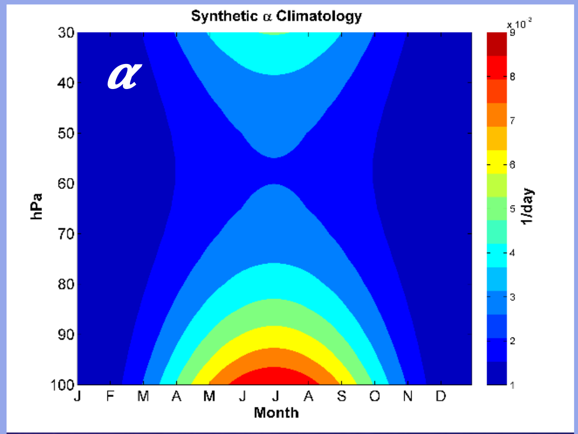
Red = maximizes
Blue = minimizes

Vertical Advection



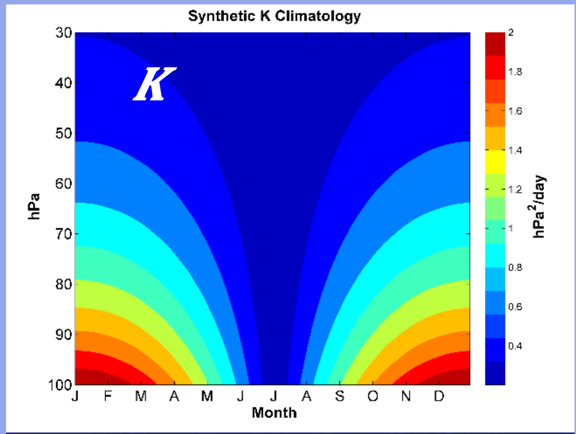
residual circulation

Horizontal Dilution



Rossby wave breaking (weak jet)

Vertical Diffusion

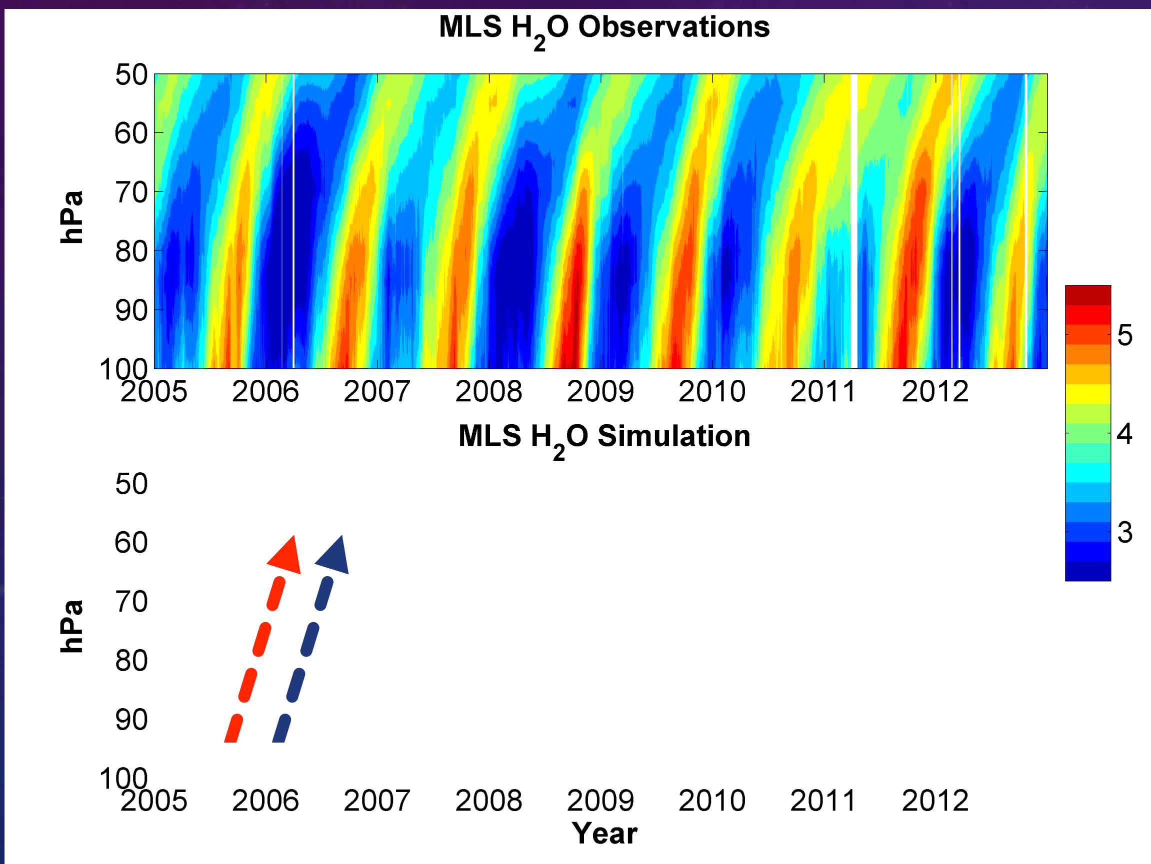


Gravity wave breaking

- Gravity waves can be generated by:
  - Overshooting cloud tops
  - Latent heat anomalies

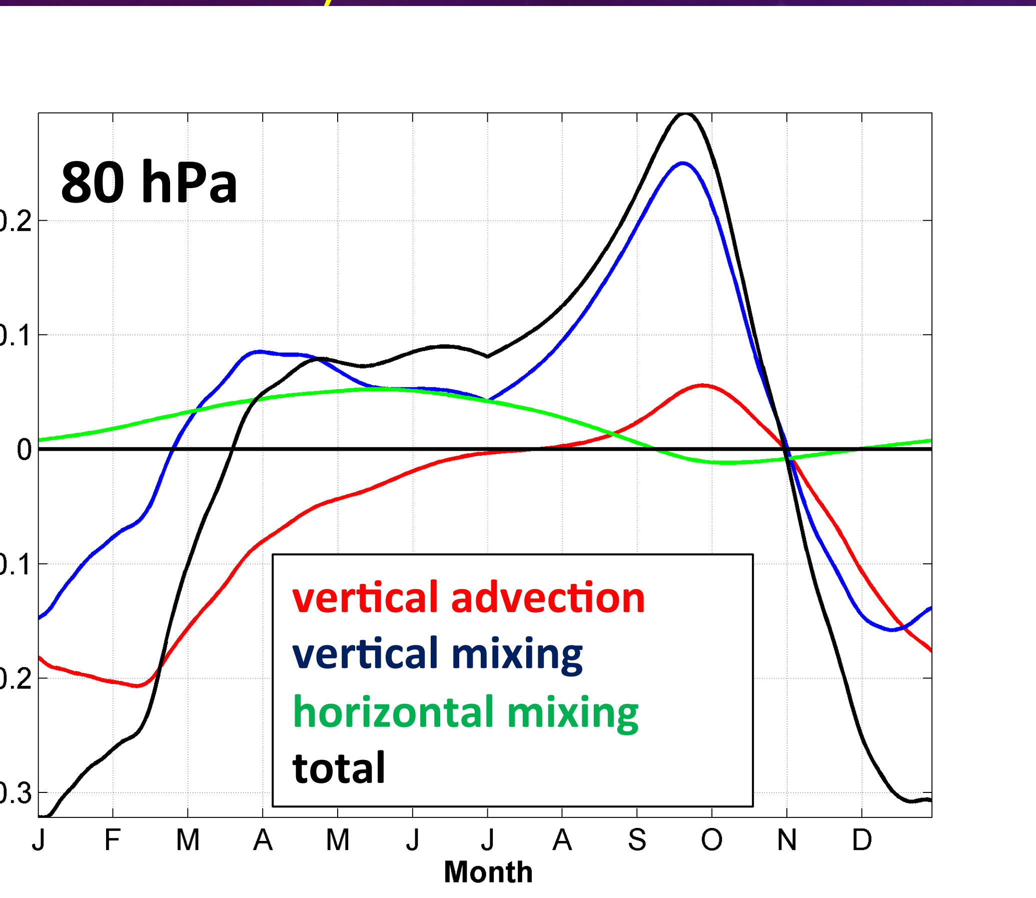
Synthetic 1-D model (from Mote et al., 1998)

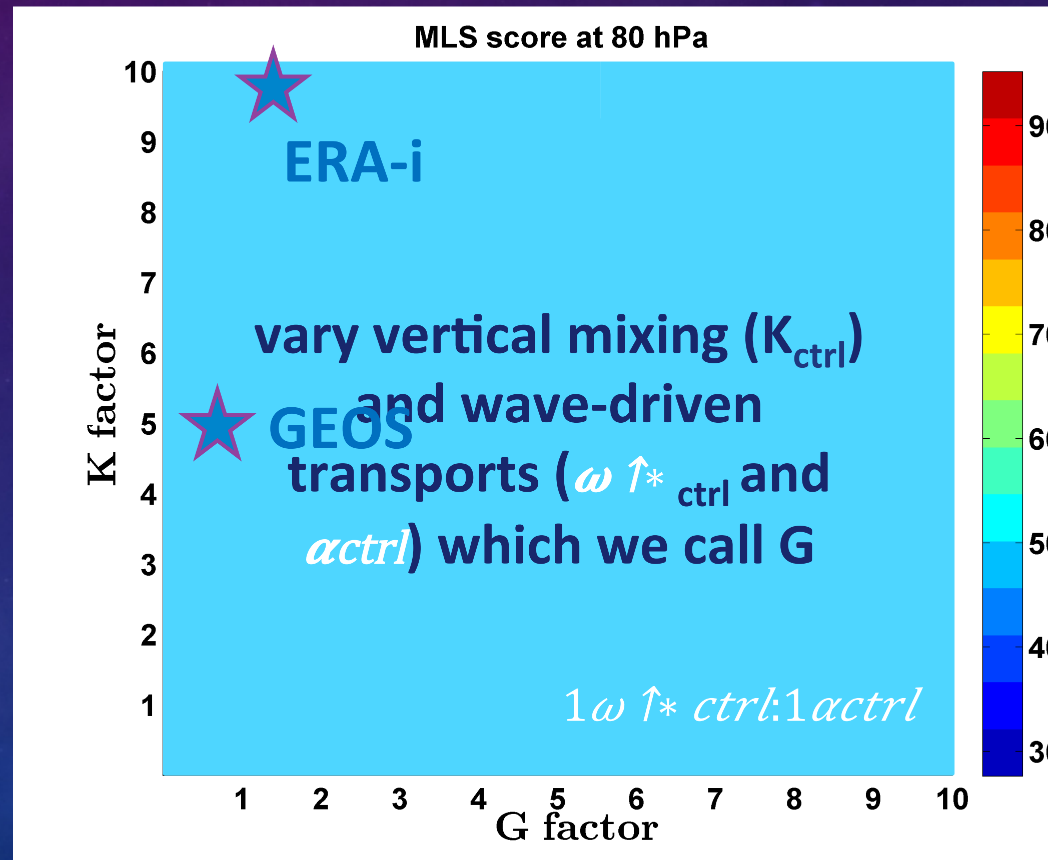
$$\partial q/\partial t = -\omega^{*}\,\partial q/\partial p + \partial/\partial p\left(K\,\partial q/\partial p\right) - \alpha\left(q - q_{midlat}\right)$$



Modeling MLS Observations

-coordinates)





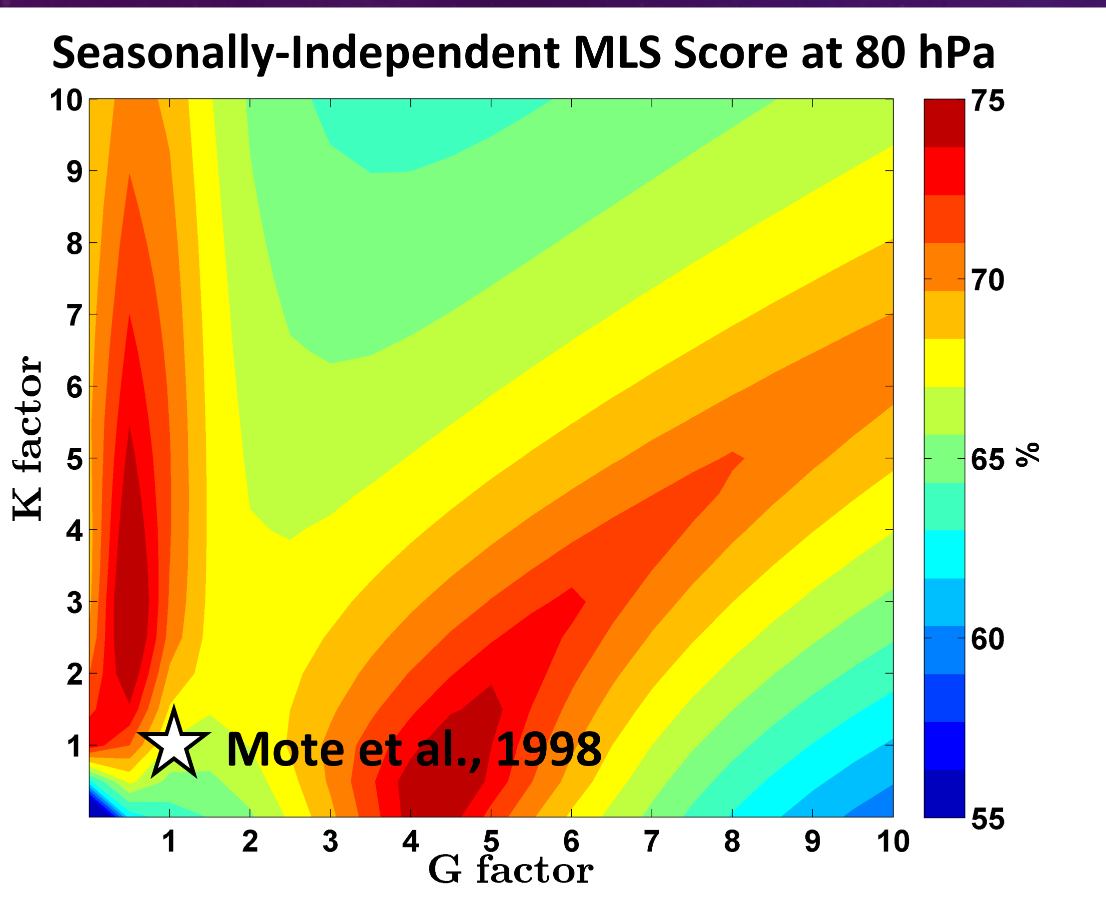
1/2 amplitude

1 month lag

Both

/hat if you use the annual mean for ALL transports?

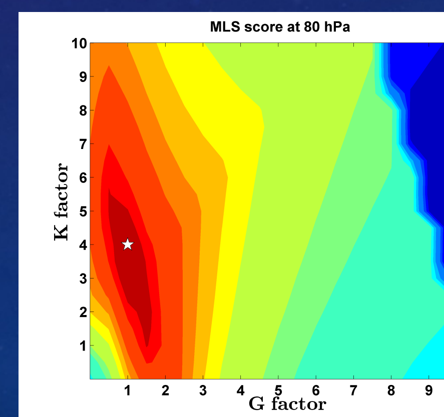
ollowing Mote et al., 1998)



Mote et al. (1998): “we have little confidence in our results below 18 km, especially for K”

Also, “Vertical diffusion has more complex characteristics below 20 km” .. such as descent coupled to convection (Sargent et al., 2014)

Using seasonally-dependent transports



ummary and implications

Vertical mixing may be **25-50% responsible for TTL transport** (even larger during JJA)

Unrealistic results appear when seasonally-independent transports are used

Spurious diffusion from data assimilation may play a large role in ERA-i

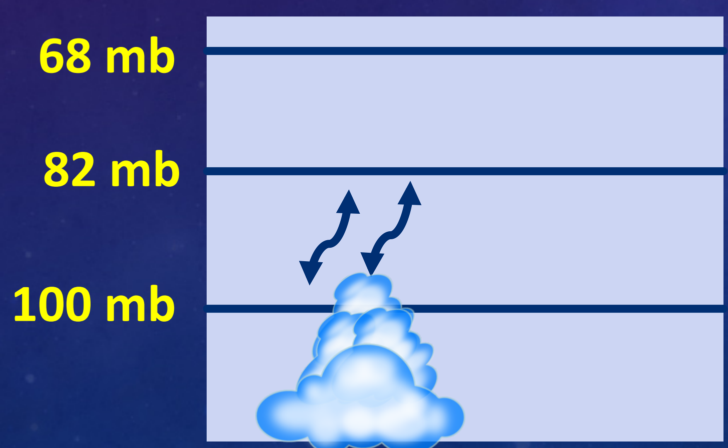
Horizontal mixing should be viewed in ***θ*-coordinates** (in-mixing becomes stronger)

- **Changes to vertical mixing** could chan global radiation balance as much as th residual circulation
  - **Phases of QBO and ENSO**
- **But the future is complicated:**
  - **Overshooting clouds? (Held and S 2006: less convective mass flux in future)**
  - **Latent heating changes?**
  - **TTL depth? (Gettelman et al., 200 thinner TTL in the future)**

Co

Limitations

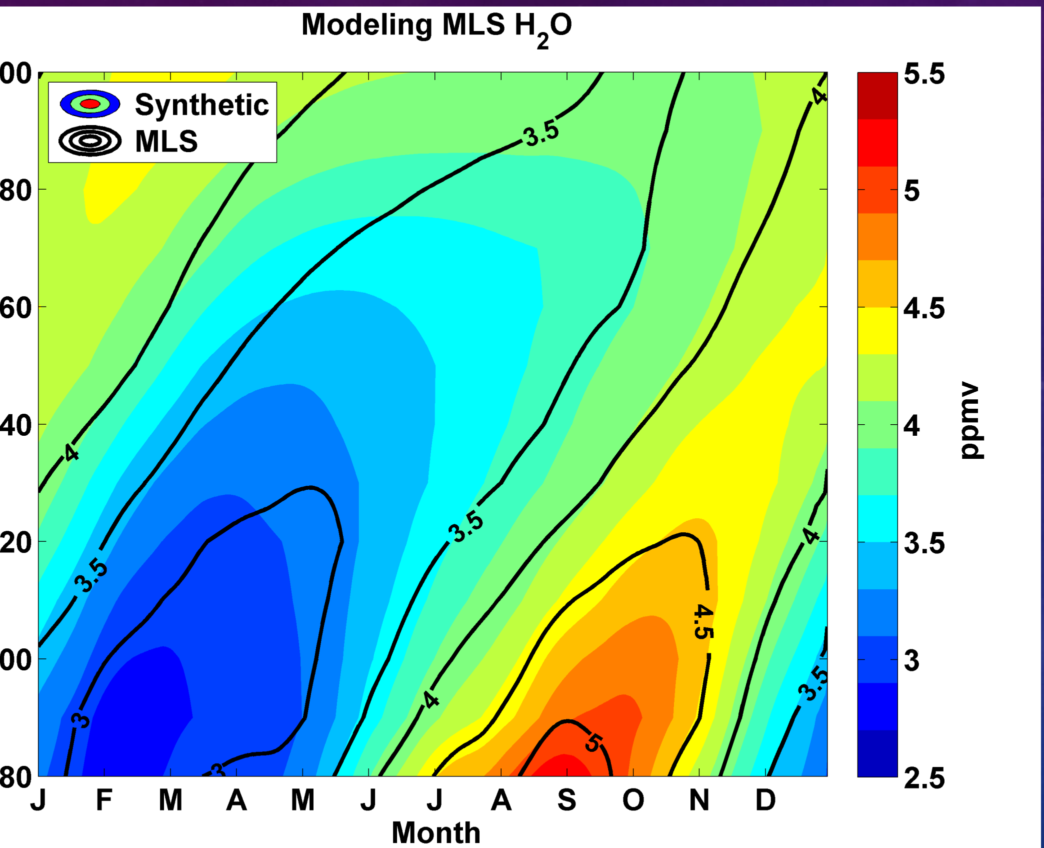
- Representation of horizontal mixing term as **linear relaxation**
- MLS vertical resolution is relatively poor, so it **may actually underestimate vertical mixing**

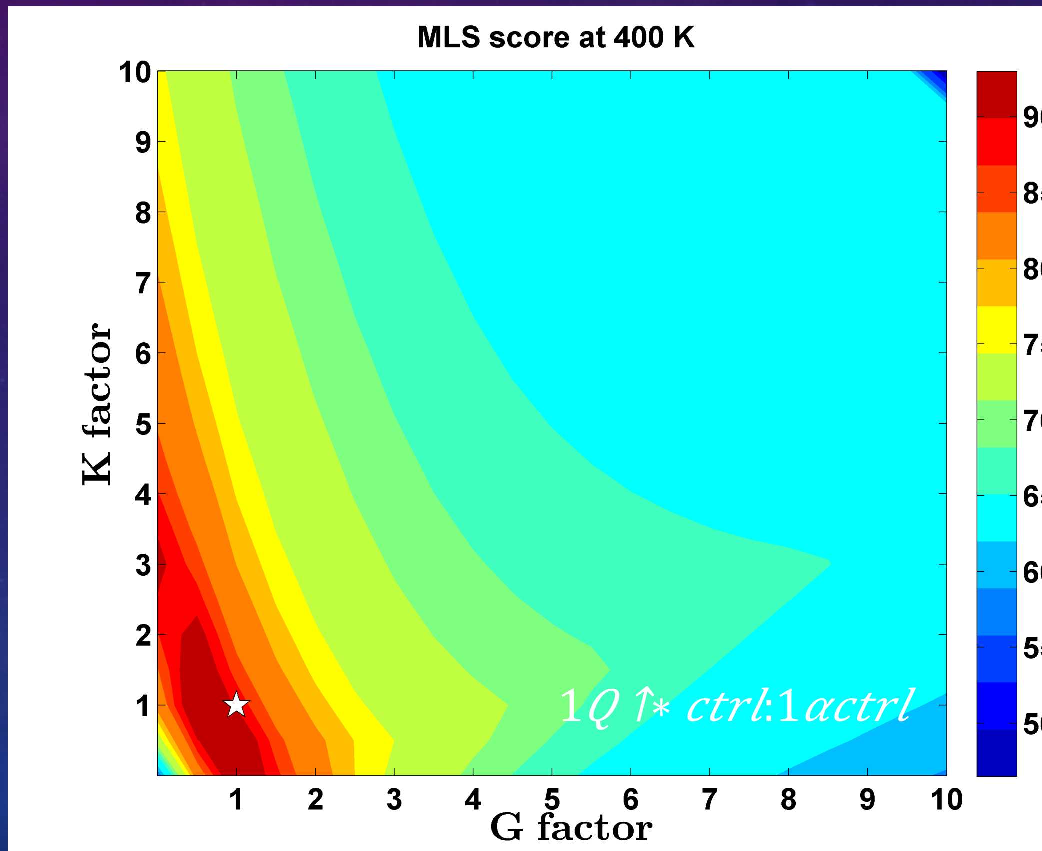


Future work

- **Test more parameters** in current tracer model (e.g., ctrl profiles)
- Parameter sweep on a **cloud-resolving model** to find what vertical mixing is most sensitive t on seasonal and longer timescale

Modeling MLS Observations (ϴ-coordinates)



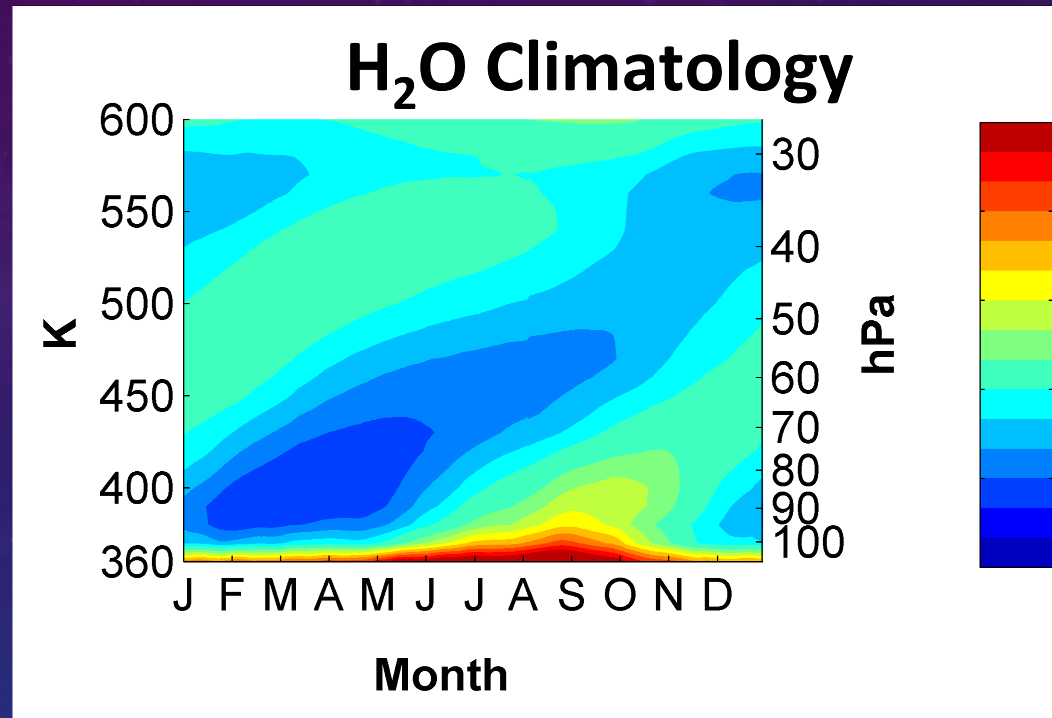


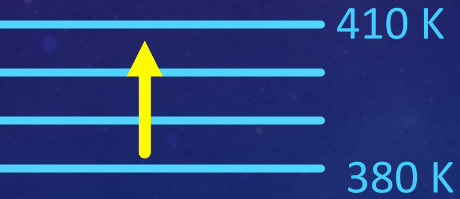
entropic coordinates

Quasi-Lagrangian framework

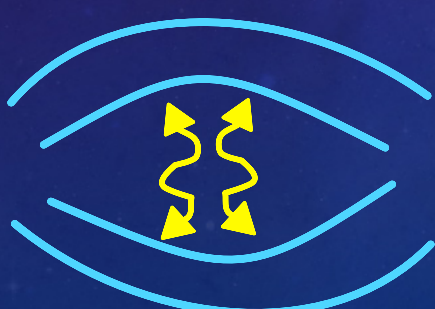
Parcels are not confined to p-surfaces as strictly (e.g., near the warm pool)

Vertical mixing is "done" by the coordinates if the process is adiabatic





vertical advection



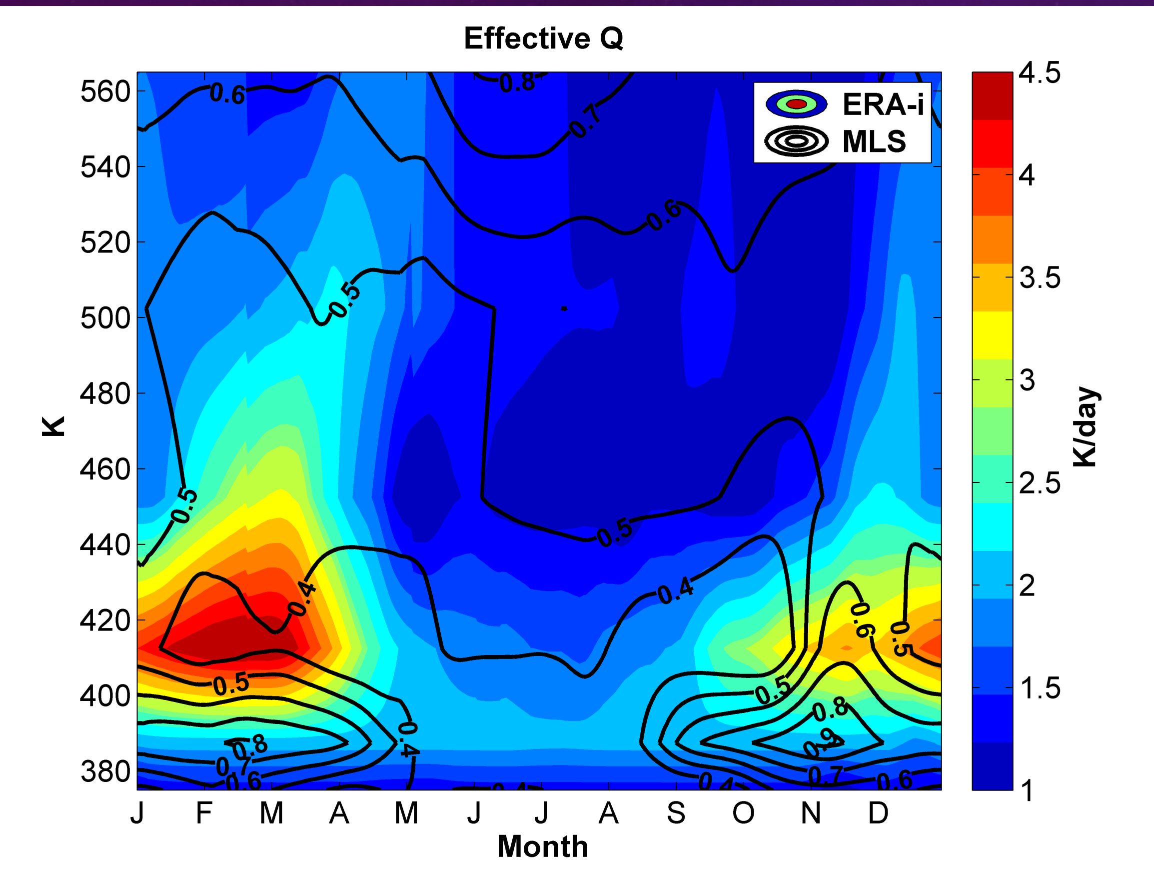
vertical mixing

$$\cancel{\partial\theta/\partial t} + \omega^{*}\,\partial\theta/\partial p + \partial\omega'\theta'/\partial p = Q$$

steady state

vertical v
in isentr
coordin

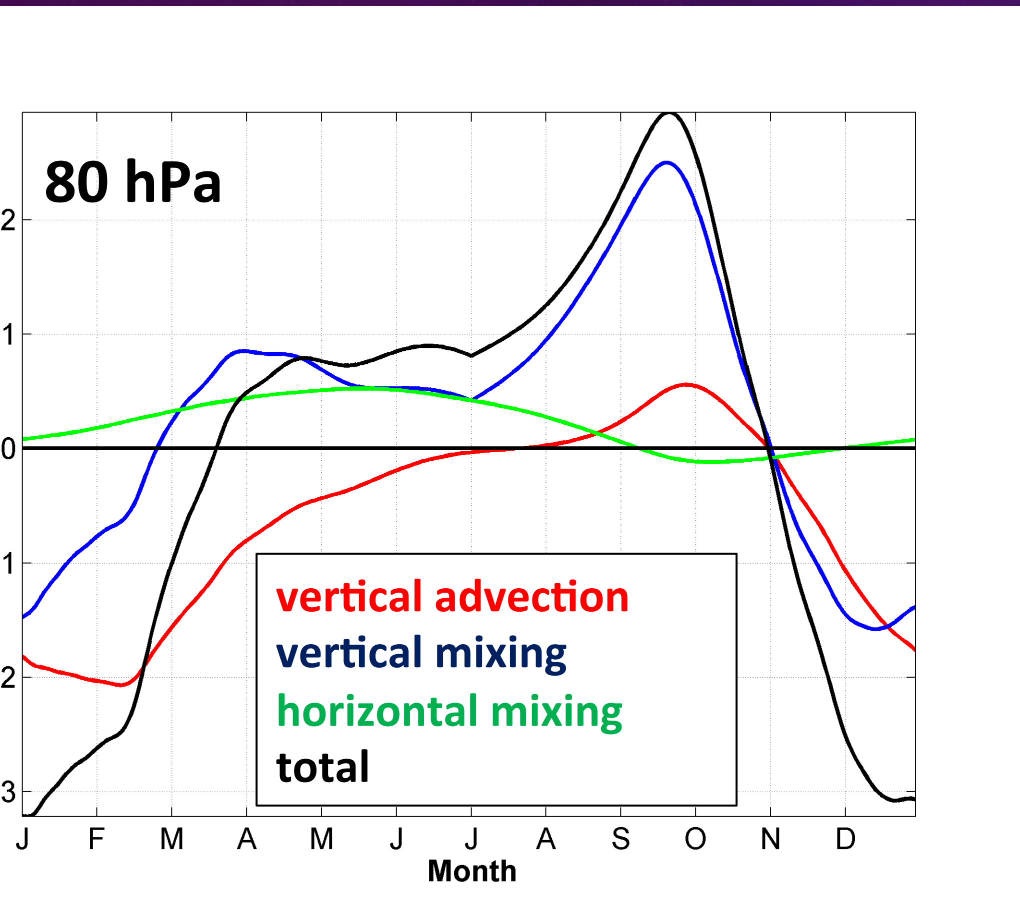
ffective diabatic heating Q

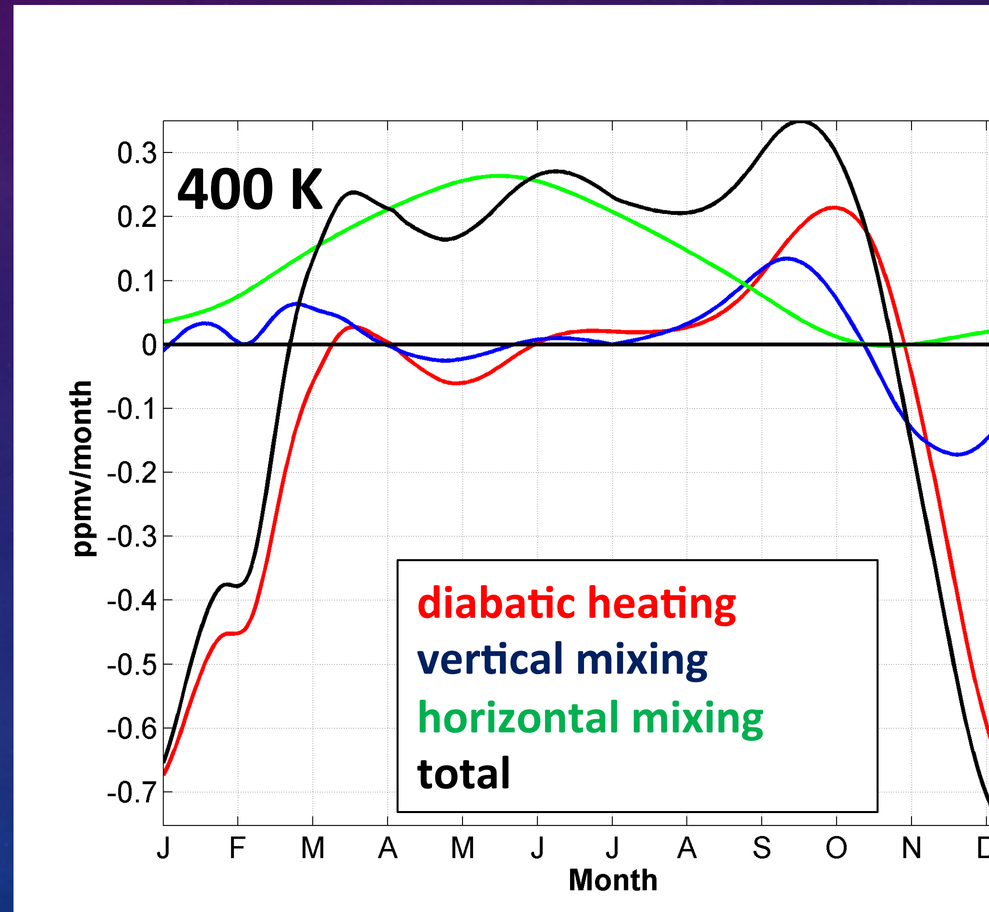


Supported by Wright and Fueglistaler (2013) and Yang et al. (2010)

→ longwave cloud radiative heating rates above 200 hPa are too strong in ERA-i

MLS Time Tendencies (p and Θ coordinates)





Note: transports are not independent of each other

TAL SCORE

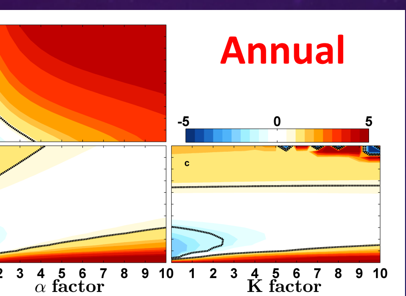
$\omega\uparrow* = advec$
$K = vertical\ di$
$\alpha = horizontal\ di$

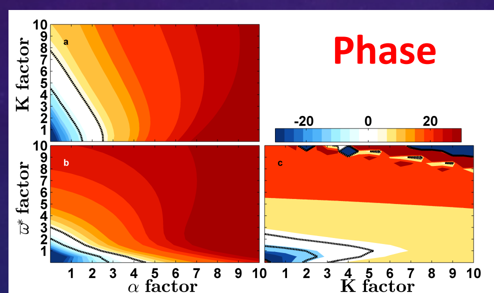
$core = 100/1 + |A\downarrow sim - A\downarrow real|/|A\downarrow real| + |\varphi\downarrow sim - \varphi\downarrow real|/|\varphi\downarrow real| + |q\downarrow sim - q\downarrow r$

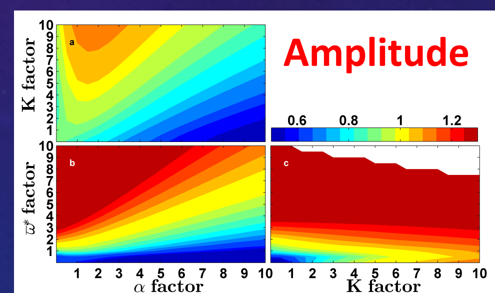
$A = amplitude$

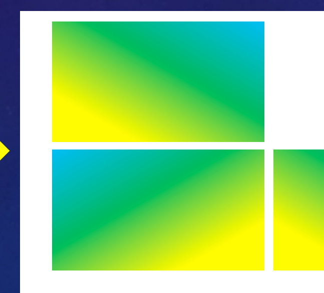
$\varphi = phase$

$q = water\ vapo$









$G = effects\ of$
$wave\ breaking\ (\omega\uparrow*\ \&\ \alpha)$

Modeling ERA-i (p-coordinates)